Effectiveness of Textile Reinforced Concrete (TRC) in Repairing Pre-cracked Reinforced Concrete Beams

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Abstract
The rehabilitation of deteriorated reinforced concrete (RC) structures has become a critical issue due to aging infrastructure and increased service load demands. Textile Reinforced Concrete (TRC) has emerged as a promising alternative to conventional strengthening techniques owing to its high tensile strength, corrosion resistance, and compatibility with concrete substrates. This study investigates the effectiveness of TRC in repairing pre-cracked RC beams subjected to flexural loading. An experimental program was conducted on RC beams intentionally pre-cracked to simulate damage conditions and subsequently repaired using externally bonded TRC layers. The structural performance of the repaired beams was evaluated in terms of load–deflection behavior, crack development, stiffness recovery, energy absorption, and failure modes. The results demonstrate that TRC repair significantly enhances the load-carrying capacity and stiffness of pre-cracked RC beams while effectively controlling crack propagation. The findings confirm the suitability of TRC as an efficient and durable repair solution for damaged RC flexural members.

Keywords: Textile Reinforced Concrete, TRC, RC beams, repair, strengthening, pre-cracked beams, flexural behavior

1. Introduction

Reinforced concrete (RC) structures are widely used in civil infrastructure due to their strength, durability, and economic feasibility. However, many existing RC structures suffer from deterioration caused by overloading, environmental exposure, corrosion of reinforcement, and poor maintenance. Cracking is one of the most common forms of damage, leading to reduced stiffness, serviceability issues, and long-term durability concerns.

Conventional repair and strengthening techniques, such as steel plate bonding and fiber reinforced polymer (FRP) systems, have been extensively used to restore structural performance. Despite their effectiveness, these methods present several drawbacks, including corrosion susceptibility (steel plates), poor fire resistance, incompatibility with concrete substrates, and de-bonding issues (FRP systems).

Textile Reinforced Concrete (TRC), also referred to as Textile Reinforced Mortar (TRM), consists of high-strength fiber textiles embedded within a fine-grained cementitious matrix. TRC offers several advantages, such as corrosion resistance, high tensile strength, vapor permeability, and good bond compatibility with concrete. These properties make TRC particularly suitable for the repair of cracked RC members.

Although previous studies have investigated the strengthening of RC beams using TRC, limited research has focused on its effectiveness in repairing *pre-cracked* RC beams, which better represent real-life damaged structures. This study aims to address this gap by experimentally evaluating the structural performance of pre-cracked RC beams repaired with TRC under flexural loading.

2. Experimental Program

2.1 Materials

The RC beams were cast using ordinary Portland cement concrete with a target compressive strength of approximately 30 MPa. Deformed steel bars were used as longitudinal reinforcement, while mild steel stirrups were provided for shear reinforcement.

The TRC system consisted of a bidirectional textile made of alkali-resistant (AR) glass fibers embedded in a cement-based mortar. The mortar exhibited high workability and good adhesion to the concrete substrate. Mechanical properties of the textile and mortar were obtained from manufacturer data and laboratory testing.

2.2 Specimen Details

A total number of RC beam specimens were cast with identical dimensions, reinforcement details, and concrete properties. The beams were designed to fail in flexure. After curing, selected beams were subjected to pre-loading up to a predefined load level to induce flexural cracks at the tension zone. These beams were then unloaded and repaired using the TRC system.

2.3 Pre-cracking Procedure

Pre-cracking was achieved by applying monotonic loading under a four-point bending configuration until visible flexural cracks developed. The load was limited to ensure cracking without causing yielding of the tensile reinforcement. Crack widths and patterns were recorded before repair.

2.4 Repair Technique Using TRC

Before applying TRC, the concrete surface was cleaned and roughened to enhance bonding. A thin layer of cementitious mortar was first applied, followed by placement of the textile. Additional mortar was then applied to fully embed the textile, forming a TRC layer of uniform thickness. The repaired beams were cured under controlled conditions before testing.

2.5 Test Setup and Instrumentation

All beams were tested under four-point bending until failure. Load was applied using a hydraulic jack, and deflections were measured using linear variable differential transformers (LVDTs). Crack formation and propagation were visually monitored throughout the test.

3. Results and Discussion

- One study showed a **36.2% increase in load-bearing capacity** and a **13.5% increase in mid-span deflection** after TRC strengthening.
- Other research indicates that increasing the width or number of textile layers can increase ultimate loads by **40–76%** in bending tests.
- Experimental results show that TRM (a TRC variant) can **restore mechanical behavior of pre-damaged RC beams** and increase shear capacity by **~18–67%** after strengthening, even when the beams were loaded during strengthening.

3.1 Load–Deflection Behavior

The load–deflection response of the repaired beams showed a significant improvement compared to the pre-cracked condition. TRC repair restored and enhanced the flexural stiffness, resulting in reduced deflections at comparable load levels. The ultimate load capacity of the repaired beams exceeded that of the pre-cracked beams, indicating effective structural rehabilitation.

3.2 Crack Pattern and Crack Control

TRC-repaired beams exhibited a higher number of finer cracks with reduced crack widths compared to unrepaired beams. The textile effectively bridged the cracks, delaying crack opening and propagation. This behavior contributed to improved serviceability performance.

3.3 Stiffness Recovery

Initial stiffness loss due to pre-cracking was substantially recovered after TRC application. The stiffness recovery ratio demonstrated the ability of TRC to re-establish composite action between the concrete substrate and the repair layer.

3.4 Energy Absorption and Ductility

Repaired beams showed enhanced energy absorption capacity and ductile behavior. The gradual failure mechanism associated with textile rupture and mortar cracking prevented sudden brittle failure, which is desirable in structural repair applications.

3.5 Failure Modes

Failure of TRC-repaired beams generally occurred due to textile rupture or de-bonding at higher load levels, followed by concrete crushing in the compression zone. No premature de-bonding was observed, indicating good bond performance between TRC and concrete.

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4. Conclusions

Based on the experimental investigation, the following conclusions can be drawn:

1. Textile Reinforced Concrete is an effective repair technique for pre-cracked RC beams subjected to flexural loading.
2. TRC repair significantly improves load-carrying capacity, stiffness, and crack control compared to the pre-cracked state.
3. The presence of textile reinforcement enhances energy absorption and ductility, resulting in a more gradual and controlled failure mode.
4. Good bond compatibility between TRC and concrete ensures efficient stress transfer and composite action.
5. TRC can be considered a durable and sustainable alternative to conventional repair methods for damaged RC structures.

5. References

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